ARTICLE

Outbreak of *Escherichia coli* O157

H7 Infections After Petting Zoo Visits, North Carolina State Fair, October-November 2004

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Objectives: To identify cases, describe the outbreak, implement control measures, and identify factors associated with infection or protection from infection, including contact with animals and hand hygiene practices.

Design: Case finding, a case-control study of 45 cases and 188 controls, environmental investigation, and molecular subtyping of clinical and environmental *Escherichia coli* O157:H7 isolates.

Setting: The 2004 North Carolina State Fair.

Participants: Case patients were fair visitors who had laboratory-confirmed *E coli* O157 infections, hemolytic uremic syndrome (HUS) diagnoses, or bloody diarrheal illnesses. Control subjects were recruited from a randomized list of persons who had purchased fair tickets online. Environmental samples from the fairgrounds were obtained from locations that had held animals during the fair.

Main Exposure: Visiting a petting zoo.

Main Outcome Measures: *Case finding:* Summary descriptive statistics of suspected, probable, or confirmed *E coli* O157:H7 infections, signs, symptoms, and HUS. *Environmental investigation: E coli* O157:H7 isolates, pulsed-field gel electrophoresis patterns, and spatial distribution of source locations. *Case-control study:* Odds ratios (ORs) comparing reported fair-related activities, hygiene practices, and zoonotic disease knowledge with outcome.

Results: A total of 108 case patients were ascertained, including 41 with laboratory-confirmed illness and 15 who experienced HUS. Forty-five case patients and 188 controls were enrolled in the case-control study. Visits to a petting zoo having substantial environmental *E coli* O157:H7 contamination were associated with illness (age-adjusted OR, 8.2; 95% confidence interval [CI], 3.3-20.3). Among children 5 years or younger who had visited the implicated petting zoo, contact with animal manure (OR, 6.9; 95% CI, 2.2-21.9) and hand-to-mouth behaviors (OR, 10.6; 95% CI, 2.0-55.0) were associated with illness. Reported hand hygiene practices did not differ significantly (OR, 1.8; 95% CI, 0.3-9.5). Reported awareness of the risk for zoonotic disease was protective (OR, 0.1; 95% CI, 0.03-0.5). Environmental samples from the petting zoo implicated in the case-control study yielded *E coli* O157:H7, with indistinguishable pulsed-field gel electrophoresis patterns from the predominant strain.

Conclusions: We describe one of the largest petting zoo outbreaks of *E coli* O157:H7 to date. Persons became infected after contact with manure and engaging in hand-to-mouth behaviors in a petting zoo having substantial *E coli* O157:H7 contamination. Use of alcohol-based hand-sanitizing gels was not protective, although knowledge of the risk for zoonotic infection was protective. Future investigations in similar outbreaks should assess risks for infection and protective measures (eg, physical barriers separating visitors from animal manure, education, and appropriate hand hygiene practices).

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INFECTION WITH SHIGA TOXIN–producing *Escherichia coli* (eg, *E coli* O157:H7) can cause hemorrhagic colitis and hemolytic uremic syndrome (HUS).[1-3] Since the late 1990s, the rate of *E coli* O157:H7 infections has declined in the United States.[4] Before these declines, an estimated 73 000 Shiga toxin–producing *E coli* (STEC) infections and 61 deaths occurred annually in the United States.[3] Although foodborne cases accounted for the largest proportion (61%) of outbreak-related infections recognized during 1982-2002,[5] outbreaks related to animal contact have grown more common.[6-10] Colonized livestock (eg, cattle, sheep, and goats) provide potential sources

See also page 96

for human exposures to STEC at farms, agricultural exhibits, and petting zoos.[11-13] Standardized management practices, including isolation and quarantine, stable environmental conditions, and less mixing between animals, may lower risks.[14]

In late October 2004, routine surveillance detected a cluster of 3 HUS cases and a surge in laboratory-confirmed STEC O157:H7 infections. Initial interviews of patients with HUS revealed they had common exposures at the North Carolina State Fair, which took place from October 15 to 24, 2004. This prompted a public health investigation. We conducted case finding and environmental investigations, followed by a case-control study that implicated 1 of 2 petting zoos at the fair. We also explored associations between illness and specific protective behaviors (eg, hygiene practices and knowledge about zoonotic disease) among visitors to the implicated petting zoo.

METHODS

CASE FINDING AND DESCRIPTIVE EPIDEMIOLOGY

After the outbreak was detected, county health department communicable disease nurses and hospital infection-control practitioners throughout North Carolina were asked to conduct active surveillance for outbreak-related STEC diarrheal illness and HUS among persons examined in emergency departments or outpatient settings or admitted to hospitals. We collected data by using standard STEC surveillance reporting forms. We modified these forms to include questions about agricultural fair and petting zoo visits. Cases were classified as follows: *suspect*: an illness in a person who was in North Carolina on October 8, 2004, or later, with onset of diarrhea (≥3 loose stools during a 24-hour period) since October 15, 2004, that lasted 2 or more days without known cause (eg, *Salmonella* isolated from stool); *probable*: suspect case with epidemiologic link to a confirmed case; *confirmed*: suspect plus either (1) laboratory-confirmed STEC or (2) clinically diagnosed HUS or thrombotic thrombocytopenic purpura after October 15, 2004, even if culture negative; and *noncases*: illnesses that did not meet other case definitions.

ENVIRONMENTAL INVESTIGATION

Investigators visited the state fairgrounds multiple times to collect information and to examine the area. Fairgrounds managers provided maps of the area and lists of activities that had occurred each day during the fair. Livestock managers provided information about all animals exhibited at the fair. This information included the number of each species at each of the areas where persons could have direct contact with animals, health certificates, dates of rotation of animals in and out of specific exhibits, and the layout of animals and pens in each area. Fairgrounds staff also provided a list of all registered food and beverage vendors who had served items at the fair, as well as information about hand sanitizer, which was provided at multiple sites at the fair.

We interviewed the Wake County Environmental Services sanitarian supervisor with oversight responsibility for vendors at the fair. We reviewed inspection records and complaint investigations. We also reviewed municipal water supply records (ie, presence or absence of coliforms and residual chlorine levels).

Investigators collected 96 initial environmental samples 10 days after the fair ended. Sample types collected included approximately 50 g of animal bedding and manure from areas where animals had been present when available and swabs from floors and of dust from exhaust fans in areas when no bedding or manure was available. Investigators also swabbed an apple cider press, collected water from a decorative fountain, and captured flies present in or near areas where animals were exhibited. Flies were transferred alive to specimen cups for shipment. Investigators received 2 convenience samples from fair visitors: bedding materials (wood shavings) from a petting zoo that a parent of a confirmed case collected from the child's stroller and shoes from an uninfected toddler who had visited the same exhibit. These shoes had visible animal manure adhering to them. Sixteen days after the initial sampling, investigators systematically resampled one area after 10 of 11 initial samples from this area yielded STEC O157:H7.

LABORATORY INVESTIGATION

Clinical

The North Carolina State Laboratory for Public Health cultured stool specimens from case patients on sorbitol-McConkey agar and further characterized STEC O157 isolates by using specific antisera, Shiga toxin assays, and pulsed-field gel electrophoresis (PFGE). Laboratory staff uploaded STEC O157 PFGE patterns to PulseNet, the Centers for Disease Control and Prevention (CDC) national molecular subtyping network for foodborne disease surveillance.

Environmental

US Department of Agriculture laboratory scientists cultured environmental samples by using sensitive selective broth enrichment, immunomagnetic separation, and plating on selective media. The STEC-positive isolates from environmental samples were sent to the CDC for PFGE and uploaded to PulseNet.

CASE-CONTROL STUDY

We designed and conducted an age-group frequency-matched case-control study to identify exposures related to illness and potential behavioral risk and protective factors among fair visitors. Questions included multiple aspects of animal contact, such as manure exposure, hand-to-mouth activities (eg, thumb sucking), and hand hygiene after exiting animal contact areas, in addition to foods and beverages consumed at the fair. To assess effects of general protective behaviors and knowledge, we included items about general hand hygiene practices and knowledge about risk for zoonotic disease transmission from animal contact.

We recruited cases from persons identified during case finding who had attended the fair and subsequently developed confirmed or probable STEC infection. A case was defined as illness in a 2004 North Carolina State Fair visitor who had at least one of the following: (1) laboratory-confirmed STEC infection, (2) HUS clinically diagnosed after October 15, 2004, or (3) bloody diarrheal illness without other known cause. Persons suspected to have acquired illness through exposure to case patients in household or child care settings were excluded.

We enrolled control subjects by using a randomized list of approximately 24 000 persons who had purchased fair tickets online or at kiosks. Controls were persons who attended the fair and remained well through November 7, 2004. Conducting interviews by telephone between November 14 and 21, 2004, we obtained consent from adult subjects directly or from parents of minor children prior to interviewing.

We sought to frequency match controls to cases in a 3:1 ratio in each of 3 age groups: 0 to 5, 6 to 17, and 18 years and older. For case patients or control subjects aged 0 to 5 years, parents were interviewed as a proxy. For case patients or control subjects aged 6 to 17 years, with parent or guardian consent, we asked both the adult and the child to participate in the interview.

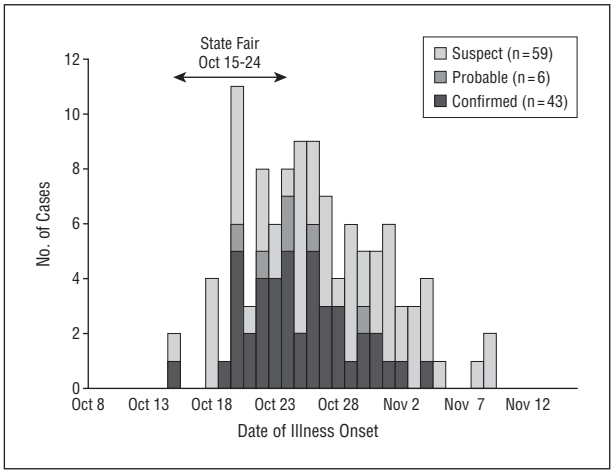

Figure 1. Illness onset dates, Shiga toxin–producing *Escherichia coli* outbreak, North Carolina State Fair, 2004 (N=108).

STATISTICAL ANALYSIS

Investigators reviewed case-finding forms for completeness and entered data into an Epi Info database (version 3.2.2, April 2004; CDC, Atlanta, Georgia). Case-finding data management and analysis were performed using Epi Info and Microsoft Access and Excel (Microsoft Corporation, Redmond, Washington). Investigators entered case-control study data into Microsoft Access databases. They performed statistical analyses by using SAS version 9.1 (SAS Institute, Cary, North Carolina) and Stata version 8.2 (StataCorp, College Station, Texas). Using logistic regression, analysts computed odds ratios (ORs) and age group–adjusted odds ratios (AORs) with exact 95% confidence intervals (CIs). Analysts used multivariate logistic regression analysis to assess associations between variables identified as independently significant. Skewed time and age distributions were analyzed using the Mann-Whitney rank sum method.

RESULTS

CASE FINDING, DESCRIPTIVE EPIDEMIOLOGY, AND LABORATORY INVESTIGATION

The investigation identified 108 outbreak-related cases (**Figure 1**). These included 41 laboratory-confirmed *E coli* O157:H7 infections and 15 HUS illnesses (**Table 1**). No fatalities occurred. The PFGE characterization of clinical isolates identified a predominant outbreak pattern; 38 of 41 laboratory-confirmed isolates (93%) shared this pattern. Median case patient age was 5.4 years (range, 1-61 years); 59% were female. Eighty-two case patients (79%) reported having visited a petting zoo at the state fair.

ENVIRONMENTAL INVESTIGATION

Records from municipal water–sampling tests, food and beverage vendor records, and investigations of complaints from patrons about food items did not support food or waterborne transmission hypotheses. Animal inspection certificates did not indicate that ill animals had remained present during the fair. Fair managers reported that they had supplied more than 280 L of hand sanitizer with 62% ethyl alcohol content during the fair to visitors of petting zoos and other animal exhibits.

Table 1. Demographic, Clinical, Laboratory, and Epidemiological Characteristics of Case Patients, North Carolina State Fair, 2004

Characteristic	No./Total No. (%)	
	Case Finding	Case-Control Study
Demographic		
Female	64 (59)	26 (58)
Aged ≤5 y	56 (52)	31 (69)
Clinical		
Diarrhea	108 (100)	45 (100)
Bloody diarrhea	63 (58)	39 (87)
Abdominal cramps	60 (56)	36 (80)
Fever	49 (45)	28 (62)
Hemolytic uremic syndrome	15 (14)	15 (33)
Laboratory		
Positive *Escherichia coli* O157 culture	41 (38)	31 (69)
Pulsed-field gel electrophoresis "pattern A"	38/41 (93)	29 (94)
Epidemiologic		
Fair visits	108 (100)	45 (100)
Petting zoo visits	82/104 (79)[a]	40 (89)

[a] Four respondents were not asked about petting zoo visits during case finding.

Environmental samples from 4 locations, including 1 of the 2 petting zoo locations, designated Petting Zoo B, yielded STEC O157 isolates (**Table 2**). The PFGE patterns from Petting Zoo B isolates were indistinguishable from the predominant clinical pattern. A second PFGE pattern emerged from isolates from another animal exhibit sample, including 2 obtained from swabbing and 1 fly pool.

Resampling of the Petting Zoo B area identified widespread and persistent STEC O157 contamination; 25 of 30 subsequent samples (83%) yielded STEC O157 isolates with PFGE patterns that were indistinguishable from the predominant clinical pattern. The majority of these samples were obtained in the area within Petting Zoo B where visitors could interact directly with approximately 100 sheep and goats (**Figure 2**). The convenience samples (shoes and shavings from stroller) were obtained after visits to Petting Zoo B. Both yielded STEC O157 with PFGE patterns indistinguishable from the predominant clinical pattern as well.

CASE-CONTROL STUDY

We enrolled 45 case patients and 188 control subjects, an overall control-case ratio of more than 4:1. Fifty-eight percent of case patients and control subjects were female. Median ages differed significantly, 3.0 and 4.8 years, respectively (Mann-Whitney rank sum, $P=.02$). Sixty-nine percent of case patients were 5 years or younger. Median ages of the 31 case patients and 115 controls within the youngest age group of fair visitors (≤5 years) differed statistically (2.2 and 3.4 years, respectively; Mann-Whitney rank sum, $P=.02$).

Table 2. Results of Environmental Testing From the North Carolina State Fairgrounds, November 3 and 9, 2004

Source Location	No. of Samples, Nov 3, 2004	Positive for *E coli* O157:H7, No. (%)	No. of Samples, Nov 9, 2004	Positive for *E coli* O157:H7, No. (%)
Petting Zoo A	16	0	4	0
Petting Zoo B	15	10 (67)	30	19 (63)
Livestock exhibits	58	5 (9)	18	0
Fresh cider exhibit	2	0	0	
Animal tie-up area	5	0	0	
Drinking fountain	0		2	0
Horse arena	0		2	0
Total	**96**	**15** (16)	**56**	**19** (34)

Abbreviation: *E coli*, *Escherichia coli*.

Figure 2. Child in Petting Zoo B, North Carolina State Fair, 2004.

Thirty-six of 45 case patients (80%) reported having visited Petting Zoo B (AOR, 8.2; 95% CI, 3.3-20.3), a finding supportive of the hypothesis generated during early case interviews that exposures during visits to Petting Zoo B resulted in infections (**Table 3**). Reported visits to 3 other exhibits that held animals were significantly associated with illness, but magnitudes of these associations were less than that for visiting Petting Zoo B. No associations between illness and foods, beverages, or other activities at the fair were noted in analysis of case-control study data.

In contrast with median ages among case patients and control subjects overall, median ages among case patients and control subjects who had visited Petting Zoo B were not statistically different within the 3 age groups. Within the 0- to 5-year age group, median ages were 2.2 and 3.0 years, respectively (Mann-Whitney rank sum, $P=.18$). Median ages among case patients and control subjects in the 6- to 17-year and 18-year and older age groups were 12.5 and 8.9 years ($P=.39$) and 51.8 and 35.8 years ($P=.41$), respectively. The 27 case patients in the 0- to 5-year age group who had visited Petting Zoo B accounted for 75% of all cases visiting this exhibit. Among the 0- to 5-year age group, case patients had odds approximately 9 times that of control subjects for having visited Petting Zoo B (OR, 9.0; 95% CI, 2.9-27.3).

Among case patients and control subjects 5 years or younger who had visited Petting Zoo B, case patients reportedly spent more time in the exhibit than control subjects (median time, 20 minutes vs 15 minutes, respectively; rank sum, $P=.04$). Touching or stepping in manure (OR, 6.9; 95% CI, 2.2-21.9), falling or sitting on the ground (OR, 3.2; 95% CI, 1.1-9.1), and engaging in hand-to-mouth behaviors (eg, thumb sucking, pacifier use, or drinking from an infant cup) (OR, 10.6; 95% CI, 2.0-55.0) were significant risk factors among this group (**Table 4**). Multivariate analysis of these 3 variables led to significant associations with hand-to-mouth behaviors (multivariate OR, 16.4; 95% CI, 1.9-138) and manure contact (multivariate OR, 11.5; 95% CI, 2.0-65.9).

While hand-washing facilities were limited to restrooms, fairgrounds staff and exhibitors provided alcohol-based hand gel disinfectant dispensers at multiple locations throughout the fairgrounds, including Petting Zoo B. High proportions of both case patients (89%) and control subjects (83%) reported hand hygiene practice, primarily by using these hand-sanitizing gels (**Table 5**).

Table 3. Associations With Illness by Visits to Different Animal Exhibits, North Carolina State Fair, 2004, Adjusted by Age

Exposure	No./Total No. (%)		AOR (95% CI)
	Case Patients	Control Subjects	
Food and Beverage Exposures			
12 Different food and beverage exposures	No statistically significant exposures identified		
Visited the cider press	2/45 (4)	24/188 (13)	0.3 (0.1-1.4)
Drank fresh apple cider	1/45 (2)	13/188 (7)	0.3 (0.04-2.4)
Animal Exhibits Visited			
Petting Zoo A	5/45 (11)	23/188 (12)	1.1 (0.4-3.3)
Petting Zoo B	36/45 (80)	64/187 (34)[a]	8.2 (3.3-20.3)
Exhibit C	21/44 (48)	50/186 (27)	2.4 (1.2-5.1)
Exhibit D	12/45 (27)	65/188 (35)	0.7 (0.3-1.4)
Exhibit E	8/42 (19)	32/186 (17)	1.2 (0.5-2.9)
Exhibit F	8/44 (18)	52/186 (28)	0.6 (0.5-1.5)
Exhibit G	31/44 (70)	94/187 (50)	2.6 (1.5-5.5)
Exhibit H, drank cider	1/8 (13)	13/40 (33)	0.4 (0.04-4.6)
Exhibit J	11/44 (25)	49/187 (26)	0.9 (0.4-2.0)
Exhibit K	11/36 (31)	56/178 (31)	1.0 (0.5-2.4)
Exhibit L	3/45 (6.7)	14/188 (7.5)	0.8 (0.2-2.8)
Exhibit M	19/44 (43)	49/187 (26)	2.4 (1.2-4.7)
Pony ride	9/45 (20)	27/187 (14)	1.4 (0.6-3.2)

Abbreviations: AOR, age-adjusted odds ratio; CI, confidence interval.
[a] Denominator includes only yes or no responses.

Table 4. Exposures Among Petting Zoo B Visitors 5 Years and Younger

Exposure	No./Total No. (%)		Odds Ratio (95% Confidence Interval)
	Case Patients	Control Subjects	
Touched or stepped in manure	19/24 (79)[a]	17/48 (35)	6.9 (2.2-21.9)
Fell down or sat on the ground	11/23 (48)	11/49 (22)	3.2 (1.1-9.1)
Sucked thumb or pacifier or drank from infant cup	8/25 (32)	2/47 (4)	10.6 (2.0-55.0)
Drank beverage or ate foods while in petting zoo	0/27	0/48	
Chewed gum, ate candy, or used a toothpick	0/27	1/48 (2)	1.0 (0-39.0)
Fed the sheep or goats	15/26 (58)	32/49 (65)	0.7 (0.3-1.9)
Fed animals in pens at the back of the tent	5/24 (21)	11/35 (31)	0.8 (0.3-2.8)
Picked up or held any sheep or goats	5/27 (19)	10/49 (20)	0.9 (0.3-2.9)
Kissed any animals	3/24 (13)	6/49 (12)	1.0 (0.2-4.5)
Sheep or goats nuzzled, nibbled, or licked	23/25 (92)	38/47 (81)	2.7 (0.5-13.7)
Picked up any object from the ground	1/26 (4)	3/49 (6)	0.6 (0.1-6.2)
Sheep or goats having reared up	10/25 (40)	14/49 (29)	1.7 (0.6-4.6)
Picked up any shavings or bedding from the ground	5/22 (23)	16/49 (33)	0.6 (0.2-1.9)
Petted or touched animals in the pens	11/25 (44)	20/46 (43)	1.0 (0.4-2.7)
Petted or touched the sheep or goats	26/27 (96)	44/49 (90)	3.0 (0.3-26.7)
Reported hand hygiene on exiting	25/27 (93)	42/48 (88)	1.8 (0.3-9.5)

[a] Denominator includes only yes or no responses.

Table 5. Hygiene Practices and Awareness of Zoonotic Disease Risks Among Case Patients and Control Subjects Who Had Visited Petting Zoo B, North Carolina State Fair, 2004

Factor	No./Total No. (%)		AOR (95% CI)
	Case Patients	Control Subjects	
Hand hygiene after Petting Zoo B visit	32/36 (89)	52/63 (83)[a]	1.7 (0.5-5.8)
Alcohol-based hand gel[b]	29/32 (91)	43/52 (83)	0.9 (0.6-1.5)
Soap and water[b]	1/32 (3)	2/52 (4)	3.0 (0.1-95.2)
Cleaned hands before eating at fair	29/36 (81)	46/64 (72)	1.6 (0.6-4.8)
Alcohol-based hand gel	20/27 (61)	19/37 (51)	2.9 (0.9-9.1)
Soap and water	10/17 (59)	21/39 (54)	1.2 (0.4-4.2)
Importance of contact with animals ("very important" or "important" compared with "not very important" or "not important")	26/36 (72)	52/64 (81)	0.6 (0.2-1.6)
Awareness of zoonotic disease risks	23/36 (64)	57/64 (89)	0.2 (0.1-0.7)
Washed before eating in general ("always" and "almost always" compared with "sometimes" or "never")	27/36 (75)	47/64 (73)	1.2 (0.5-3.1)
Carry personal hand sanitizer	24/36 (67)	43/63 (68)	1.1 (0.4-2.9)
Bite nails	14/36 (39)	21/64 (33)	1.2 (0.5-2.8)

Abbreviations: See Table 3.
[a] Denominator includes only yes or no responses.
[b] Compared with no reported hand hygiene.

Reported hand hygiene practice among Petting Zoo B visitors was not protective (AOR, 1.7; 95% CI, 0.5-5.8), nor was use of hand-sanitizing gels compared with no hand hygiene practice (AOR, 0.9; 95% CI, 0.6-1.5). Only 1 case patient and 2 control subjects who had visited Petting Zoo B reported using soap and water to clean hands after exiting the exhibit.

More control subjects reported awareness that certain diseases can spread from contact with livestock (AOR, 0.2; 95% CI, 0.1-0.7). No difference was detected in how case patients and control subjects valued the importance of visiting animal exhibits. Case patients and control subjects who had visited Petting Zoo B reported no significant differences between general hand-washing practices before meals, use of personally carried hand sanitizers, or fingernail-biting behaviors.

COMMENT

Our investigation identified Petting Zoo B as the source of this large *E coli* O157:H7 outbreak and identified risk factors for infection. Environmental, epidemiologic, and analytic studies produced complementary results. Young case patients had visited this petting zoo more frequently than other animal exhibits. They reported longer visits in this contaminated environment, reported more contact with manure, sat or fell on the ground more often, and engaged in more hand-to-mouth behaviors in this area than control subjects. The majority of case patients and control subjects reported use of alcohol-based hand-sanitizing gels after visiting Petting Zoo B; however, we were unable to demonstrate whether use of

hand-sanitizing gels or washing hands before eating was protective. In contrast, reported awareness of risks for zoonotic disease was associated with a protective effect among visitors to this exhibit.

Other studies have demonstrated that hand-to-mouth activities place young children at risk for different infections.[15,16] Duration of exposure among persons who visited a farm in Pennsylvania was positively associated with *E coli* O157:H7 infections.[15] Our findings that extended exposure duration and hand-to-mouth activities were associated with disease in this outbreak are consistent with earlier findings.

A key finding in this study is an apparent lack of protection associated with reported hand-hygiene practices. In other outbreaks, hand-hygiene practices that included hand washing with running water and soap demonstrated protective effects.[15] Hand washing was not a common practice among either case patients or control subjects during our investigation. However, more than 90% of case patients reported use of alcohol-based hand gels with no evident benefit. Multiple factors might have led to this finding. Exposures sufficient to lead to infection might have occurred before hand hygiene practice within the contaminated petting zoo environment, or clothing might have become sufficiently contaminated while in the petting zoo and led to exposures after leaving the exhibit. Samples obtained weeks after the fair ended from the Petting Zoo B site and from clothing worn by patrons grew the outbreak pattern of STEC O157, demonstrating the extended viability of the pathogen. In addition, differences between hand hygiene practices and their effectiveness have been found in other studies. For example, washing hands with soap and running water before use of alcohol-based hand gels is preferred when hands are visibly soiled and has been shown to be effective in reducing hand contamination in health care settings.[17-19]

Most case patients (64%) reported awareness of disease risk from contact with livestock. Although more controls (89%) reported awareness of this risk, the benefits of effective education may not sufficiently reduce risks during animal contact activities.

Recall bias among case-control study respondents might have affected study results. Recall might have varied between parents of case patients, some of whom faced crises associated with seriously ill children, and control subjects' parents, who did not face such threats. Further limitations include potential selection bias because control subjects were patrons who had purchased tickets online or at kiosks by using credit cards, whereas case patients were identified through case finding.

Seventy-five percent of all case patients enrolled in the case-control study were aged 0 to 5 years. Narrower stratification of this age group might have reduced the likelihood of dissimilar median ages identified among case patients and control subjects in this stratum—a threat to comparability. Although median ages were not significantly different among visitors to the implicated petting zoo, further stratification might have also permitted fuller analysis of behaviors among young children with important relationships to infection risk (eg, hand-to-mouth behaviors or picking up objects from the ground).

Nine case patients (20%) from the case-control study had not visited Petting Zoo B. Clinical isolates from 2 case patients were indistinguishable by PFGE and differed from the predominant outbreak strain. These case patients' PFGE patterns were indistinguishable from PFGE patterns obtained from animal Exhibit C environmental isolates. The remaining 7 case patients' isolates produced PFGE patterns that did not match any environmental isolate. Sources of these infections remain unclear, but other exposures leading to isolated or limited clusters of infections likely occurred during the fair.

In response to the outbreak, we advised the North Carolina Department of Agriculture and Consumer Services to adopt guidelines to prevent future outbreaks in settings where substantial numbers of persons can interact with animals that might be shedding pathogens. In response to other zoonotic disease outbreaks associated with petting zoos and farms, the National Association of Public Health Veterinarians developed disease-prevention guidelines for settings where visitors have direct contact with animals that might shed pathogens.[19] In addition to adopting these guidelines, we also recommended state fair managers require use of fencing or similar barriers in petting zoos to prevent or restrict contact with manure. We also recommended petting zoo managers forbid eating or use of infant cups and pacifiers while in exhibits and consider age-related restrictions or requirements for supervision of young children.

Education about avoidance of potential zoonotic disease risks is warranted when contact with animals is expected, particularly for persons with substantial risk for severe disease (eg, young children, older adults, pregnant women, and immunocompromised persons).[19] Enhancing education through additional supervision is warranted. Multiple formats for education should be used, such as signs, stickers, handouts, and verbal information. Use of recorded audio messages encouraging visitors to clean hands after visiting animal exhibits and warning persons with higher risks for severe disease might help reinforce hygiene and protection messages.

Despite recognition of the preventive potential of hand hygiene, this investigation did not provide evidence to support specific hand hygiene practices. Guidelines for such exhibits as petting zoos recommend and emphasize use of running water and soap for hand hygiene.[19] Further study of hand hygiene practices in such settings might clarify methods that can sufficiently reduce hand contamination. Careful evaluation of hand hygiene practices should occur to identify features associated with adequate protection. Hospital infection-control guidelines for hand-sanitizing gel use indicate that visibly soiled hands should be cleaned by using soap and running water before gel use,[17] but guidelines designed for health care workers might not translate into adequate practice in other settings. Petting zoos should work to prevent exposure to pathogens by using engineered barriers.

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